IMPTAM

Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM Runs at CCMC

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1. IMPTAM, an overview

IMPTAM
Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM is a physical model of the inner magnetosphere developed at the Finnish Meteorological Institute by Natalia Ganushkina et al. (e.g., 2001, 2005, 2006, 2013, 2014, 2015).

The model traces electrons and ions in the keV range from the nightside plasma sheet into the inner magnetosphere and near the plasmasphere.

It is a well-established model in the community with dozens of papers and presentations.

IMPTAM for electrons has been run nearly continuously using real-time data since September 2013; results viewable at *http://imptam.fmi.fi*. *http://fp7-spacecast.eu*, and *http://csem.engin.umich.edu/tools/imptam/*

1. IMPTAM, an overview

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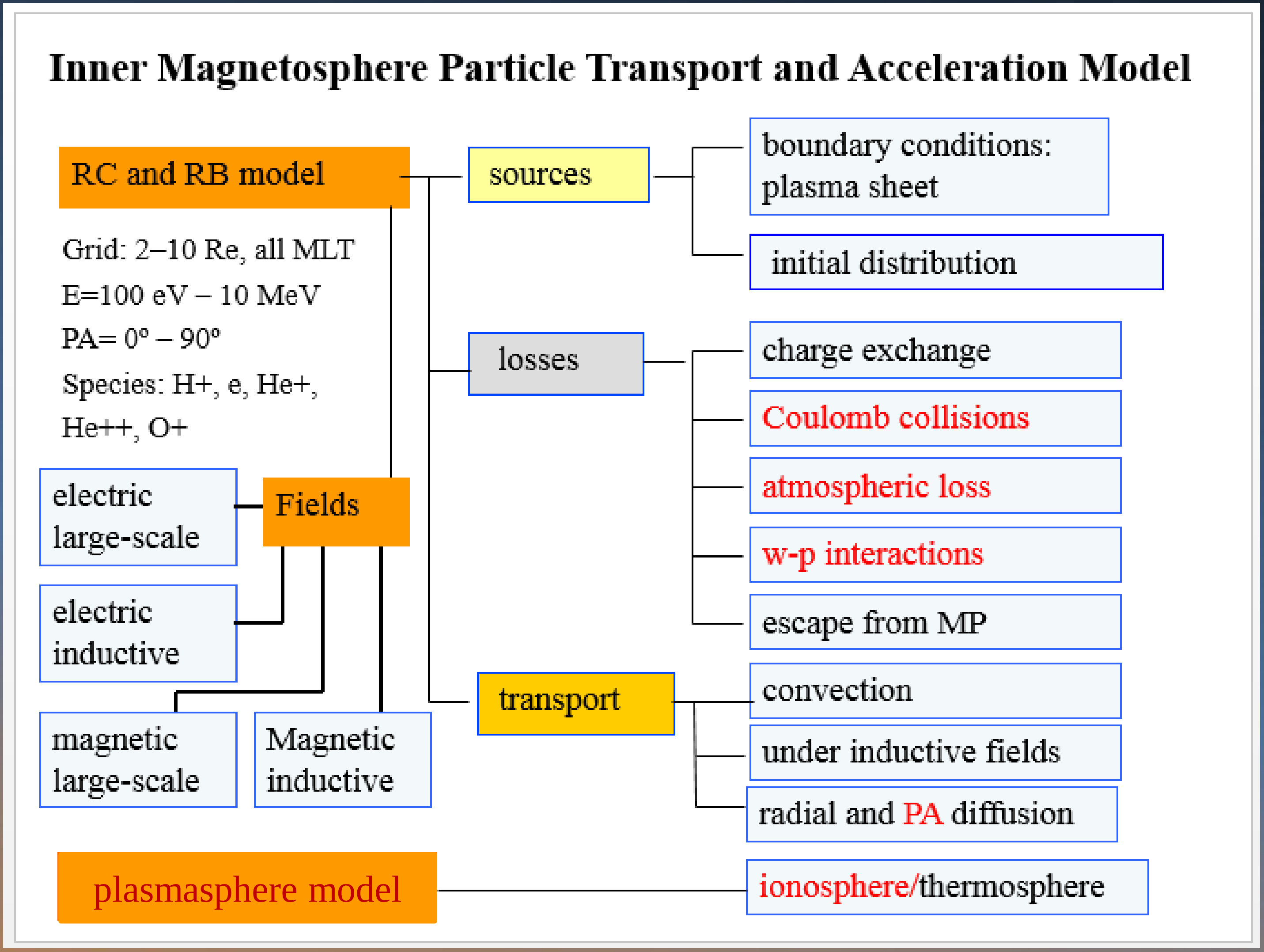
Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM traces **ions and electrons** with arbitrary pitch angles from the plasma sheet to the inner L-shell regions with energies 1 to 300 keV in time-dependent magnetic and electric fields

- traces a distribution of particles in the **drift approximation** under the conservation of the 1st and 2nd adiabatic invariants. Liouville's theorem is used to gain information of the entire distribution function
- for the obtained electron distribution function, we apply **radial diffusion** by solving the radial diffusion equation
- **losses: charge exchange** (ions), **pitch angle diffusion** (electrons), and **convection outflow**
- advantage of IMPTAM: **can use any magnetic or electric field model**, including self-consistent magnetic field and substorm-associated electromagnetic fields

1. IMPTAM, an overview

IMPTAM
Inner Magnetosphere Particle Transport and Acceleration Model



Internal models used in IMPTAM nowcasting

Inner Magnetosphere Particle Transport and Acceleration Model

Magnetic field model: *Tsyganenko* T96 (Dst, Psw, IMF By and Bz)

Electric field model: *Boyle et al.* (1997) (Vsw, IMF B, By, Bz)

Boundary conditions at 10 Re: kappa distribution with number density and temperature given by *Tsyganenko and Mukai* (2003) model (Vsw, IMF Bz, Nsw)

Radial diffusion for electrons with diffusion coefficient D_{LL}

$$D_{LL} = 10^{0.056Kp - 9.325} L^{10}$$

(*Brautigam and Albert,* 2000)

Losses: depend on Kp index, magnetic field

Strong diffusion (L=10-6):

$$\tau_{sd} = \left(\frac{\gamma m_0}{p} \right) \left[\frac{2\Psi B_h}{1-\eta} \right]$$

(*Chen et al*., 2005)

Weak diffusion (L=2-6):

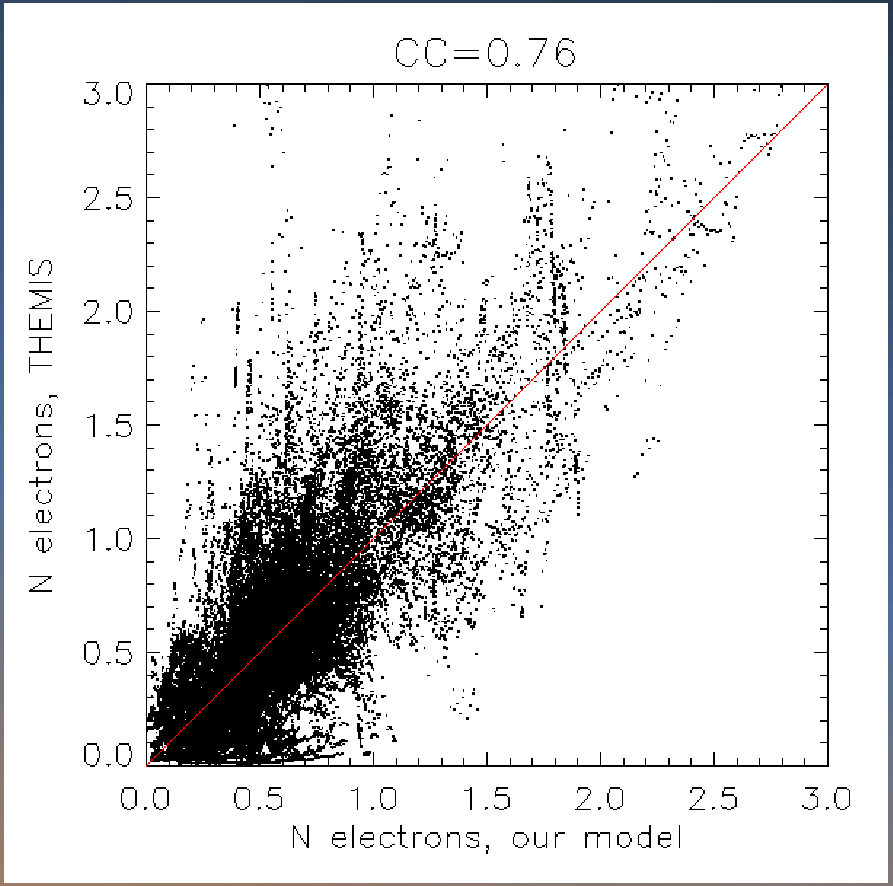
$$\tau_{wd} = 4.8 \cdot 10^4 B_w^{-2} L^{-1} E^2, \;\; B_w^2 = 2 \cdot 10^{2.5+0.18Kp}$$

(*Shprits et al*., 2007)

IMPTAM Inner Magnetosphere Particle Transport and Acceleration Model

2. Current research with IMPTAM

Empirical model for plasma sheet electron density (and temperature) at 6-11 R_e based on THEMIS data that is now applied for the plasma sheet source in IMPTAM.



2. Current research with IMPTAM

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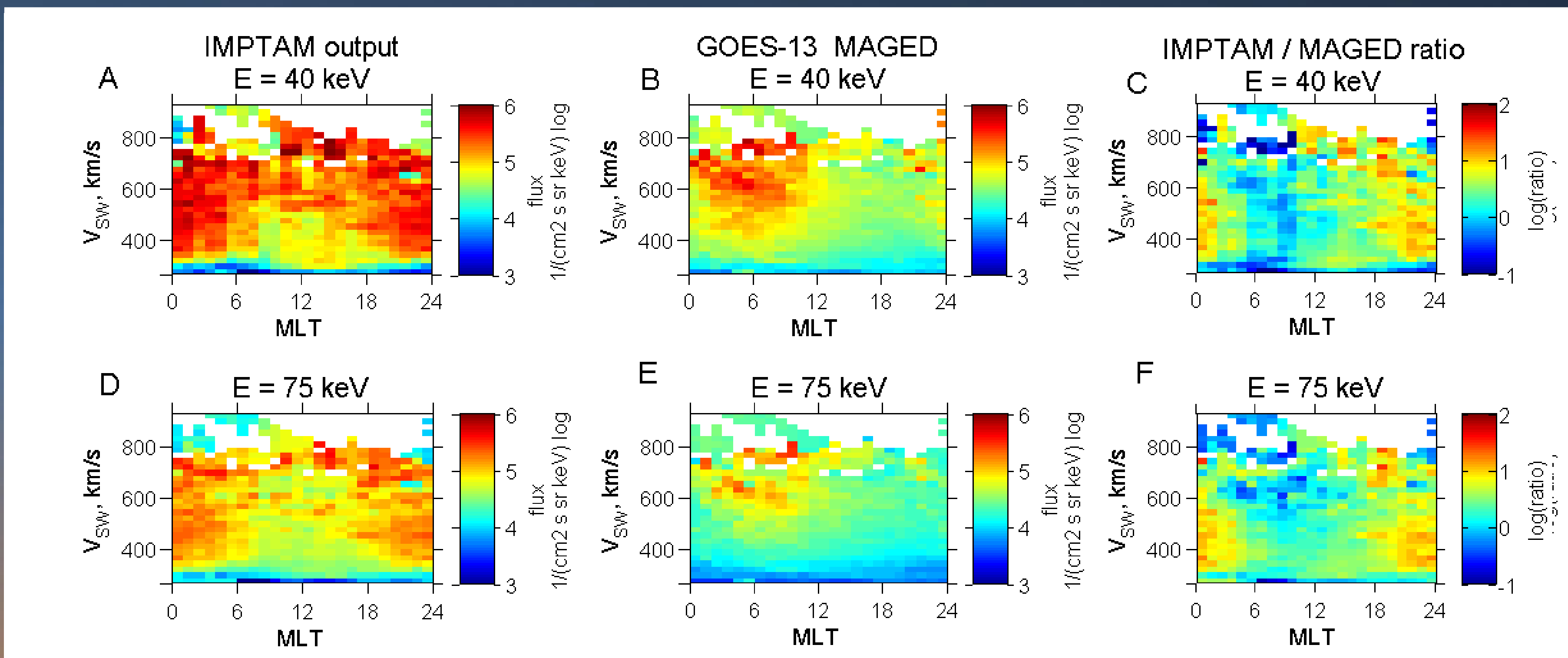
Comparison on nearly two years of IMPTAM nowcasting results for Goes-13's geosynchronous orbit: input parameter effects



2. Current research with IMPTAM

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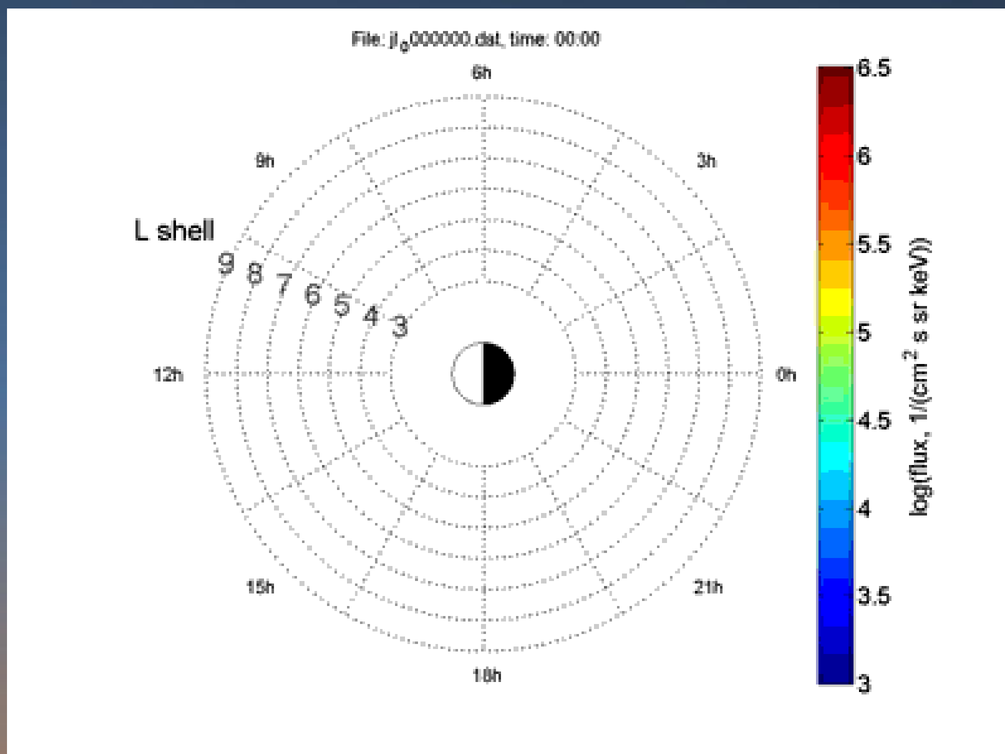
Video of a modeled January 2, 2005 charging event:

equatorial electron fluxes



2. Current research with IMPTAM

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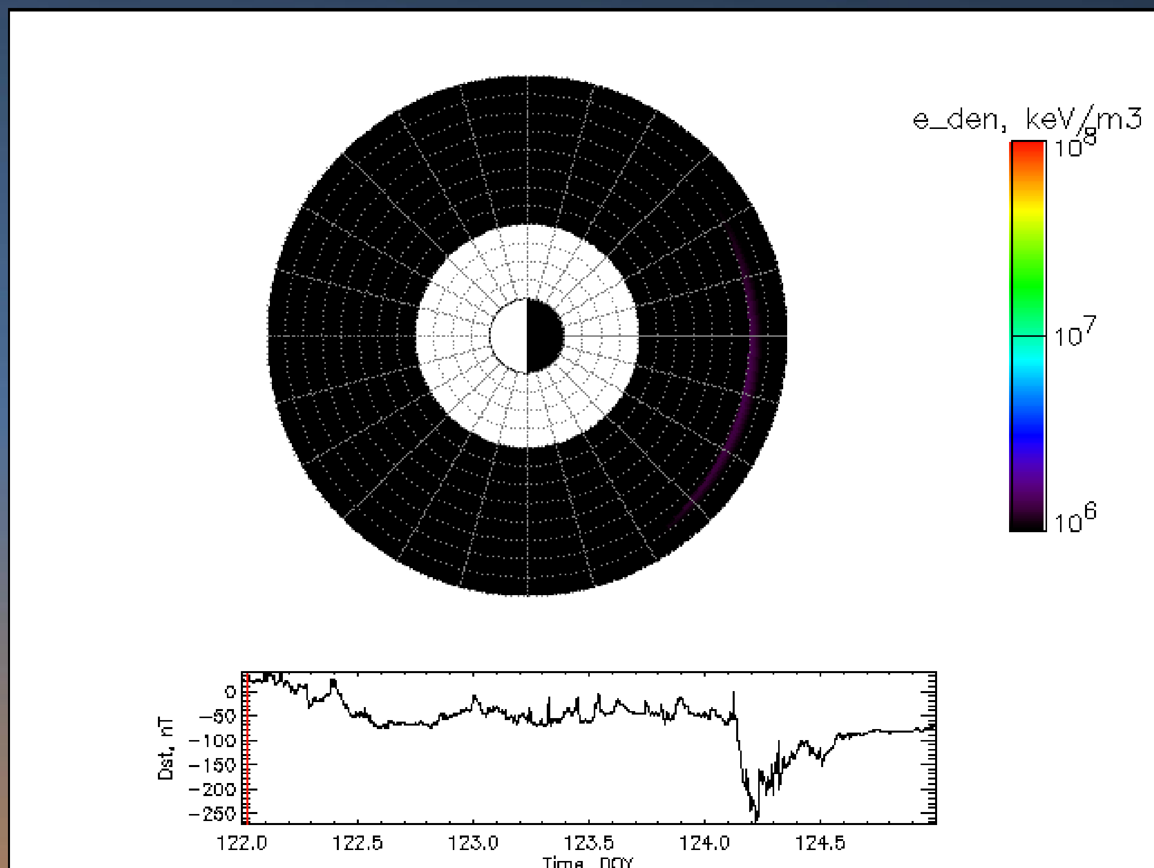
Role of substorm-associated electromagnetic pulses in the ring current formation during May 2-4, 1998 storm: energy density for ions



3. IMPTAM nowcasting

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IMPTAM is continuously run with real-time solar wind data and geomagnetic indices for nowcasting.

Currently the model is run hourly.

IMPTAM nowcasting has been running since September 2013, and it hasn't had gaps in results for last 12 months.

The model responds to all changes in the solar wind and handles also extremes and storm times well.

The results are shown on our website *http://imptam.fmi.fi* as well as on *Michigan University's CSEM* website and *www.fp7-SpaceCast.eu*

3. IMPTAM nowcasting

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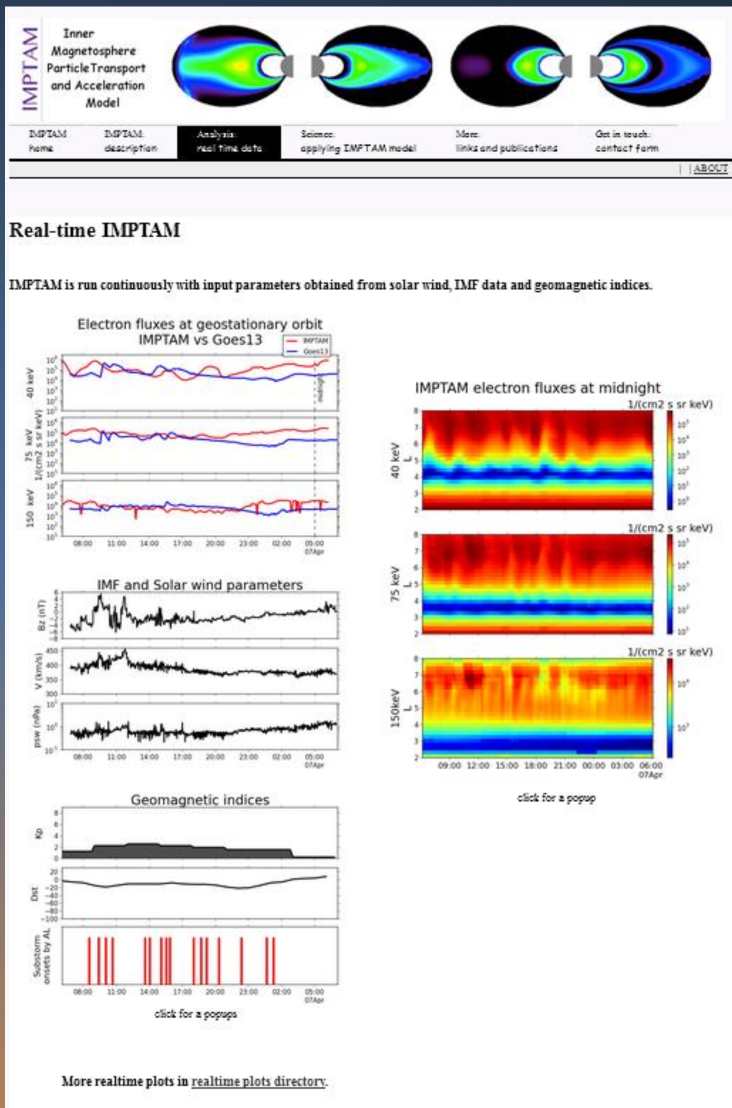


<u>IMPTAM webpage real-time view</u>

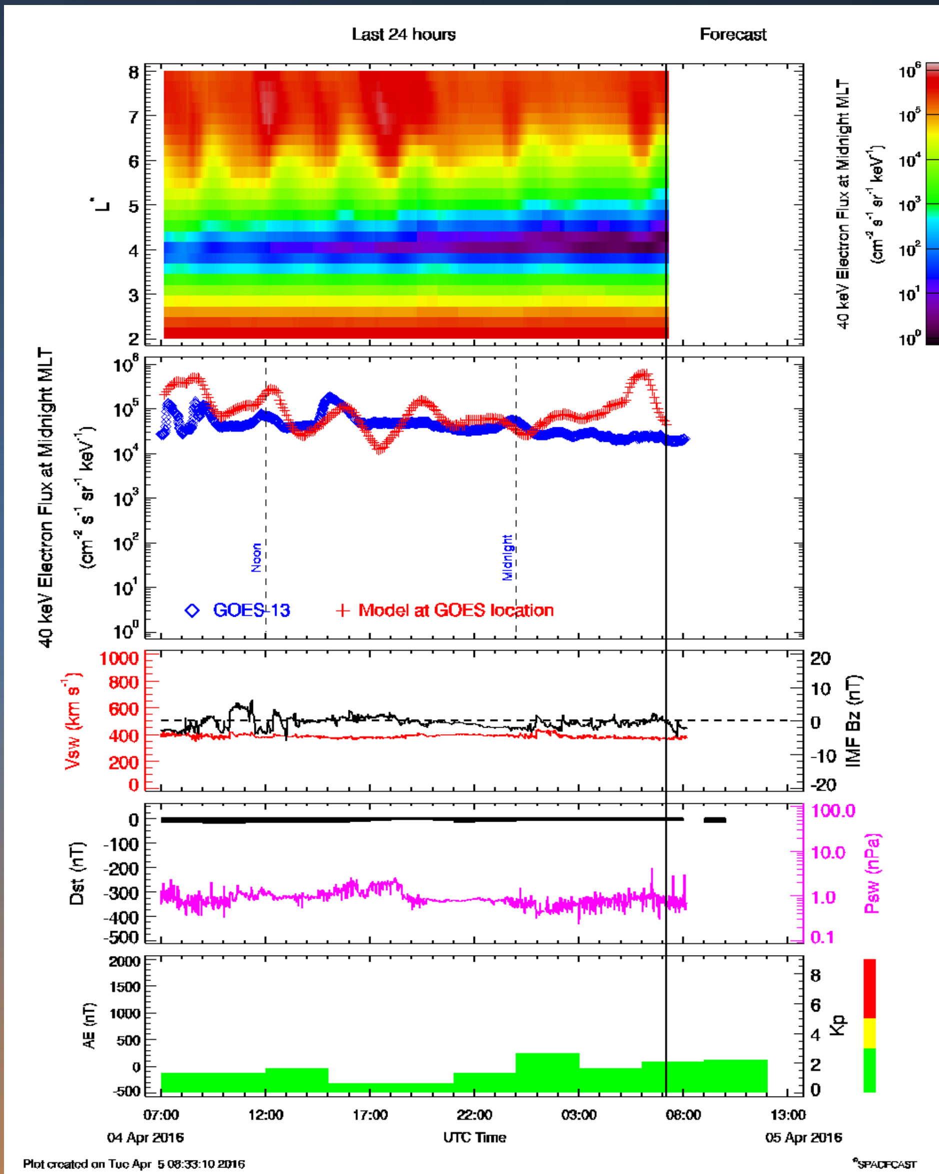
Electron fluxes for the midnight from L= 2 to 8 are provided as well as for the Goes-13 location. IMPTAM electron fluxes are compared with Goes-13 MAGED instruments fluxes for energies of 40, 75 and 150 keV.

Key input parameters from the solar wind and geomagnetic indices are also presented.

3. IMPTAM nowcasting

Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM



<u>SpaceCast webpage real-time view of 40 keV electrons</u>

Electron fluxes for the midnight are provided. IMPTAM fluxes are compared with Goes-13 MAGED instruments fluxes for electron energies of 40, 75 and 150 keV.

Key solar wind and geomagnetic indices are also presented.

4. IMPTAM Instant Run

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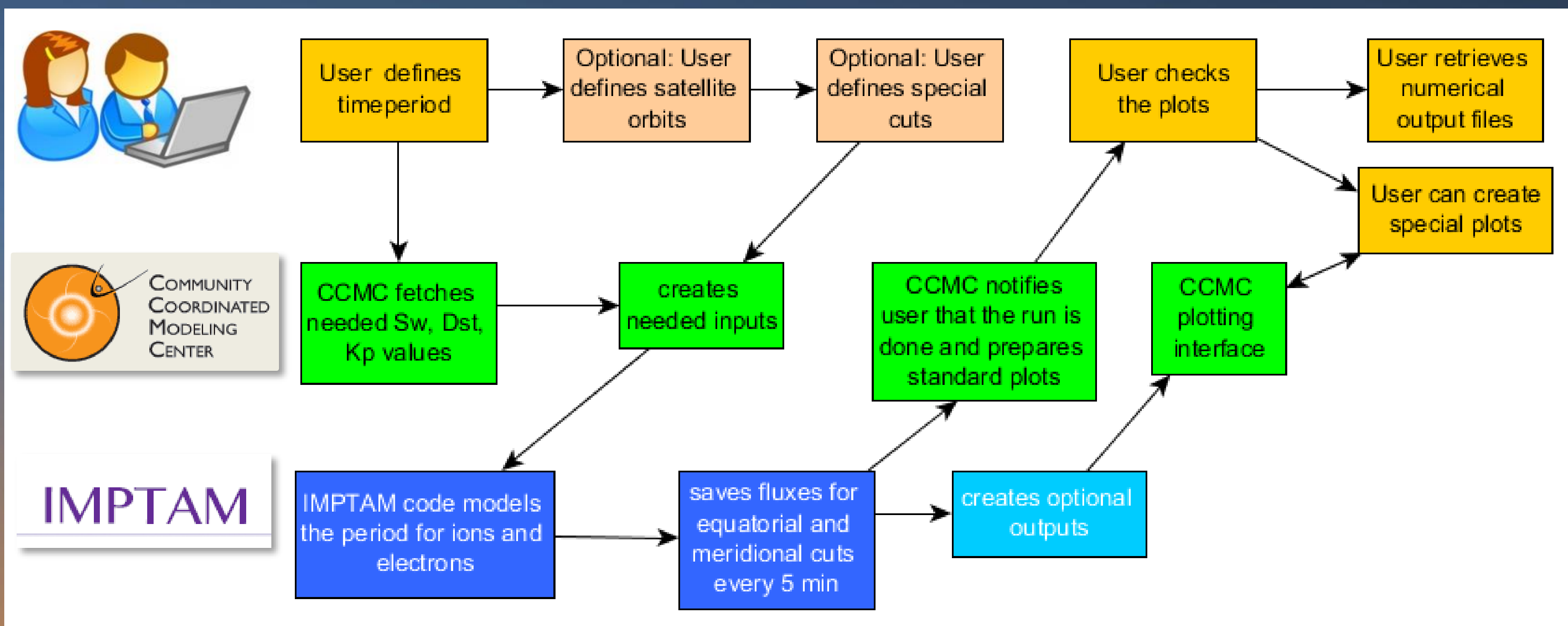
IMPTAM setup for CCMC Instant Run

Provides ion (H^+, He^+, He^{++}, O^+) and electron fluxes for 1-300 keV anywhere within $L<10\ R_E$, and for all pitch angles every 5 minutes



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5. Summary and Outlook

IMPTAM is well suited for CCMC runs:

- The model is robust with all solar wind and geomagnetic conditions.
- It is an established scientific tool in space weather research.
- It is being actively developed.

Future developments:

Automated substorm pulse generation from realtime AL index:

After it has been tested with IMPTAM nowcasting,

IMPTAM code for CCMC Instant Run will feature the same.

User options for models used for magnetic field, electric field, etc.

Additional Slides 1

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Some IMPTAM papers:

1. Sillanpää et al., Long-term variations of electron fluxes at geostationary orbit: GOES MAGED data and IMPTAM, in preparation.
2. Ganushkina et al., Nowcast model for low-energy electrons in the inner magnetosphere, Space Weather, 13, 2015.
3. Ganushkina et al., Low energy electrons (5-50 keV) in the inner magnetosphere, J. Geophys. Res., 119, 2014.
4. Ganushkina et al., Transport of the plasma sheet electrons to the geostationary distances, J. Geophys. Res.: Space Physics, 118, 2013.
5. Ganushkina et al., Storm-time ring current: model-dependent results, Ann. Geophys., 30, 2012.
6. Ganushkina et al., Evolution of the proton ring current energy distribution during 21–25 April 2001 storm 2006, J. Geophys. Res., 111, 2006.
7. Ganushkina et al., Role of substorm-associated impulsive electric fields in the ring current development during storms, Ann. Geophys., 23, 2005.
8. Ganushkina et al., Formation of intense nose structures, Geophys. Res. Lett., 28, 2001.